

UNIVERSITY OF CALIFORNIA
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THE COMPOSITION OF CANNING TOMATOES

L. G. SAYWELL AND W. V. CRUESS

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The Composition of Canning Tomatoes¹

L. G. SAYWELL² and W. V. CRUESS³

INTRODUCTION

The yield and quality of tomato products depend in great measure upon the composition of the raw material. Nevertheless, tomatoes are purchased by canners and tomato-products manufacturers without regard to this fact. The price paid for sugar beets, on the other hand, usually varies according to their sugar content. The investigation reported upon in this publication was undertaken in order to determine whether the variation in composition of canning tomatoes is sufficient to warrant differences in price in accordance with the concentrations of the desirable constituents, and to ascertain to what extent locality, variety, seed selection, water supply, date of picking, and other factors might affect these constituents. Owing to the present rapidly increasing production of canned tomato juice, information on the concentration of the more important constituents of tomatoes is particularly desirable at this time.

REVIEW OF THE LITERATURE

Atwater and Bryant (1906)⁴ published proximate analyses of a number of vegetables, including analyses of tomatoes, but gave no comparative results and did not give the source of the samples reported upon. In a recent publication Chatfield and Adams (1931) have given the following average, maximum, and minimum values for several of the constituents of tomatoes: sugar, 3.37, 4.06, and 2.30 per cent; starch, less than 0.1 per cent; protein, 1.00, 1.80, and 0.70 per cent; and total solids, 5.90, 9.4, and 3.3 per cent.

Meyers and Croll (1921) reported on the carbohydrate content of two samples of tomatoes. Bell, Long, and Hill (1926), in studies on human metabolism, found the available carbohydrates (soluble sugars) of the tomatoes used in their studies to range from 2.6 to 3.0 per cent. Lawrence and McCance (1929) found an average of 2.4 per cent soluble sugars in tomatoes.

¹ Received for publication May 12, 1932.

² Research Assistant in Fruit Products.

³ Associate Professor of Fruit Products and Chemist in the Experiment Station.

⁴ See "Literature Cited," pages 31 to 32, for complete data on citations, which are referred to in the text by author and date of publication.

All of the investigations cited above were made by those chiefly interested in the nutritional value of tomatoes. The following citations are of papers upon the physiology of the tomato plant, and upon the composition of the fruit in relation to its value for canning or manufacturing purposes.

Bornträger (1925), in studies of changes occurring during ripening, reported that citric and malic acids are the only organic acids present in the ripe fruit.

Rosa (1925, 1926), in studies made at the University Farm, Davis, California, upon the changes occurring during ripening of several varieties of tomatoes used for the fresh market, found the reducing sugar of mature, sound tomatoes of the Earliana, Globe, and Stone varieties to range from 2.63 to 3.80 per cent, sucrose less than 0.10 per cent, starch 0.012 to 0.052 per cent and total acid-hydrolyzable material, 0.180 to 0.212 per cent. That is, invert sugar made up most of the carbohydrate substance.

Benoy and Webster (1930) found no sucrose and stated that all sugar present in tomatoes is invert. They gave the average sugar content as 2.43 per cent and starch as 0.069 per cent.

Bigelow and Fitzgerald (1915) made an extensive study of the composition of tomato pulps, both the raw and the partially concentrated products, from many factories, principally in the eastern and middle western United States. The raw pulp reported upon by them is the mixed unconcentrated juice and screened flesh free of skins and seeds. The average composition of 11 samples reported by them was: total solids, 4.37 per cent; total acid as citric, 0.31 per cent; and sugar as invert, 2.19 per cent.

Bigelow and Stevenson (1923) elaborated upon the previous work of Bigelow and Fitzgerald and prepared tables showing the relation between specific gravity of filtrate and total-solids content of tomato pulp; and the relation of refractive index to total solids of tomato catsups. They also devised a formula expressing the relation of refractive index to per cent total solids in tomato pulp.

Huelsen (1925) prepared tables giving the total solids and refractive index of tomato pulps of various concentrations made from tomatoes grown in the eastern United States.

Cruess and Saywell (1928) and Cruess, Saywell, and Mark (1929) reported that locality and climate are important factors affecting the composition of tomatoes. Cruess and Saywell (1929) have indicated that the relation of refractive index to total solids for California tomatoes is not identical with that given by Huelsen (1925) for eastern tomatoes.

MacGillivray (1929) has published comparative analyses of different portions of the fruit of three varieties of tomatoes grown in Indiana. In each variety the jelly-like pulp had the highest acidity and the inner locule pulp the highest total-solids content.

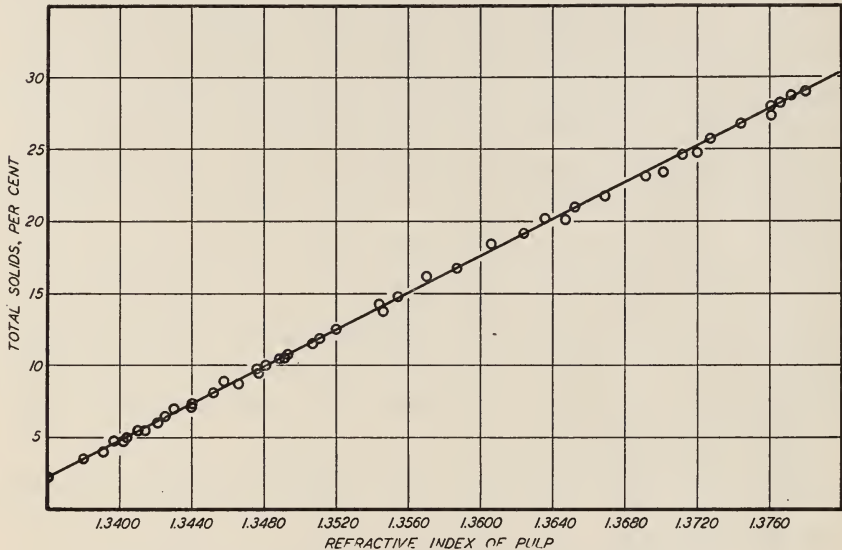


Fig. 1.—Graph showing the relation of refractive index to total solids of tomato pulp.

METHODS OF ANALYSIS

Most of the analyses were made upon the pulp, which consists of the screened whole fruit free of skin, seeds, and coarse fiber, but containing in finely divided form practically all of the red pulpy portions of the fruit. However, in a number of instances the entire fruit was used for analysis. Many of the pulp samples were secured from the pulping machines in canneries. Where whole tomatoes were used in preparing pulp for analysis the fruits were quartered through the polar diameter and two alternate quarters of each fruit were retained. These were then ground coarsely in the laboratory by means of a kitchen-sized food grinder and were rubbed through a monel-metal screen of approximately $\frac{1}{16}$ -inch mesh. The samples of pulp taken in canneries were preserved by heating in sealed cans. Those prepared in the laboratory were preserved by storage at 0° to 10° F in the frozen condition. Comparative analyses showed no detectable change in composition by either method of preservation.

During the seasons of 1925 and 1926 the total-solids content was determined by drying 5-gram samples to constant weight in a vacuum oven at 70° C and 28 to 29 inches vacuum, as recommended by the Association of Official Agricultural Chemists (1925). In subsequent seasons many of the values for total solids were determined from the refractive index. Readings were made upon the juice by means of an Abbé refractometer, and the corresponding total solids were obtained from a graph constructed by plotting the refractive indexes (obtained in 1925 and 1926) against the total solids determined by drying at 70° C.

In establishing the curve shown in figure 1, which gives the relation of total solids of the pulp to refractive index of the pulp, more than 100 samples of natural and of partly concentrated pulps were examined. Determinations of total solids were made by drying samples in a vacuum oven at 70° C, and the refractive index was determined upon a few drops of the juice at 20° C. Samples from twenty-one different localities, representing all important tomato-producing sections of the state, were used in this standardization. None of the samples contained any added salt or sugar.

Trial calculations show that the total-solids content of the pulp of California tomatoes is given with reasonable accuracy by using the following formula:

$$TS = 781 (n_D - 1.3332) - 123 (n_D - 1.3396)$$

where TS is the total solids in percentage by weight and n_D the refractive index at 20° C. If the reading is made at any other temperature than 20° C, add to the observed refractive index 0.0001 for each degree Centigrade above 20° C and subtract 0.0001 for each degree below 20° C. In the formula, 1.3332 is the refractive index of pure water at 20° C and 1.3396 is the refractive index of tomato pulp containing 5 per cent total solids. At 5 per cent solids the expression $123 (n_D - 1.3396)$ becomes $123 (1.3396 - 1.3396) = 0$.

Below 5 per cent solids the value of this expression is negative and must be added to the expression $781 (n_D - 1.3332)$, i.e., a double negative is a positive. For example, an observed refractive index is 1.3382. $TS = 781 (1.3382 - 1.3332) - 123 (1.3382 - 1.3396) = 3.91 - (-0.172) = 3.91 + 0.172 = 4.08$.

Above 5 per cent total solids this expression is subtracted. Thus the observed refractive index of a pulp is 1.3472. $TS = 781 (1.3472 - 1.3332) - 123 (1.3472 - 1.3396) = 10.934 - 0.934 = 10.00$ per cent total solids.

Total acid was determined by titration of 10 cc of the clear filtrate from the pulp with 0.1 normal sodium hydroxide using phenolphthalein indicator. The acidity is expressed as citric acid in grams per 100 cc.

For the sugar determination a weighed sample of the pulp was diluted to mark in a volumetric flask and clarified by addition of a small amount of finely powdered Horne's lead subacetate and filtered; the excess lead was removed by precipitation with powdered potassium oxalate, and a second filtration. Reducing sugars in this filtrate were determined by the Shaffer-Hartmann (1921) iodometric method.

Tomatoes are known to contain only a very small proportion of sucrose. The sucrose content of a few samples was determined by the Shaffer-Hartmann method after hydrolysis of the sucrose with dilute hydrochloric acid. However, in order to determine the accuracy of this method, a representative sample of freshly prepared pulp was divided

TABLE 1
COMPARISON OF VARIOUS METHODS OF INVERSION OF SUCROSE
IN TOMATO PULP

Sample No.	Per cent total sugar				Per cent reducing sugar
	10 per cent citric acid	5 cc conc. HCl per 25 cc for 10 min.	5 cc conc. HCl per 25 cc for 7 min.	Invertase 1 hour at 55° C	Untreated control
1	3.792	3.708	3.792	3.792	3.760
2	3.792	3.708	3.780	3.788	3.756
3	3.785	3.708	3.788	3.790	3.764
Average	3.790	3.708	3.787	3.790	3.760

into five portions. The first portion was hydrolyzed by heating on a steam bath at 100° C for 10 minutes with 10 per cent of citric acid; the second was similarly heated with 5 cc of concentrated HCl per 25 cc aliquot for 10 minutes; the third portion was heated for 7 minutes with 5 cc of concentrated HCl per 25 cc aliquot on the steam bath; the fourth portion was treated with invertase at 55° C for 1 hour, a method that inverts only the sucrose and not hemicelluloses, etc.; and a fifth portion was used as an untreated control. All hydrolyses were conducted in triplicate. The acidified samples were neutralized. All were clarified as previously described and reducing sugars were determined in the filtrates by the Shaffer-Hartmann method. Table 1 gives the data on the fresh, or wet, basis.

It is apparent that 10 minutes heating with HCl was too severe and resulted in loss of some sugar. Heating with HCl for 7 minutes, however, gave results agreeing closely with those obtained by inversion with invertase. Therefore, the method of heating 7 minutes with HCl was adopted, since it is more rapid and convenient than inversion with invertase.

It was thought that some inversion of sucrose by invertase possibly present in the tomatoes might occur during preparation and storage of the samples. Accordingly 0.2 gram of sucrose per 100 cc was added to freshly prepared pulp. Another portion with no sucrose added served as a control. Both were held at 55° C, the optimum temperature for invertase action, for 1 hour. Analyses of both samples were made in triplicate. There was no evidence of invertase action and it was concluded, therefore, that no detectable inversion would occur during preparation of the samples, storage at a freezing temperature, and subsequent thawing.

Acid-hydrolyzable material, which includes starch, was determined on a few samples by hydrolyzing the unfiltered sample for 2½ hours at 100° C on a steam bath with 20 per cent by volume of concentrated HCl. Other substances hydrolyzable by HCl, such as pentosans, as well as starch are determined by this method.

Starch in several samples was determined by hydrolysis with diastase by a modification of the method of Olmsted (1920). To a 25 cc aliquot was added 0.1 gram of Taka diastase. The sample was held at 55° C for 1 hour. It was then cooled, clarified, and the sugar determined by the Shaffer-Hartmann method (1921). A blank determination was made with 0.1 gram of diastase dissolved in 25 cc of water.

Nitrogen was determined on weighed portions by the Kjeldahl method, using an oxidizing mixture of H_2SO_4 , CuSO_4 , and K_2SO_4 ; protein was taken as 6.25 times the weight or percentage of nitrogen.

EFFECT OF LOCALITY ON COMPOSITION OF TOMATOES

In the investigation on the effect of locality on composition, the total solids and total-acid content of samples taken from the various important tomato-growing sections of the state during the five seasons, 1925, 1926, 1927, 1928, and 1929 were determined. In order to minimize the effect due to seed variation, plants of the same stock were grown at Davis and Berkeley and the composition of the fruit compared.

Effect of Locality on Total Solids and Acidity of Commercially Grown Tomatoes.—Since only total solids and total acid were determined on the majority of the commercially grown samples these data are considered separately from the data on sugar content, protein, starch, and pH value presented later in this report.

For greater ease of comparison, the values for total solids and total acid given in table 2 are presented as averages, maximums, and minimums only. From 4 to 30 samples were used in calculating most of the averages; in three cases only one sample was analyzed.

TABLE 2

TOTAL SOLIDS AND TOTAL ACID OF TOMATOES FROM DIFFERENT LOCALITIES

Variety	Locality	Year	Number of samples	Total solids, per cent			Total acid, grams per 100 cc		
				Average	Maximum	Minimum	Average	Maximum	Minimum
San Jose Canner.....	Alameda County	1925	6	7.02	7.89	5.86	0.48	0.77	0.29
		1927	9	6.61	7.70	5.30	0.39	0.50	0.33
		1928	10	7.73	8.50	6.50	0.30	0.41	0.23
		1929	13	7.67	8.80	6.20	0.34	0.42	0.26
	Sacramento.....	1925	8	4.99	5.75	4.65	0.33	0.41	0.27
		1926	18	5.85	6.40	4.80	0.31	0.33	0.22
		1927	6	6.50	7.60	5.60	0.29	0.33	0.26
		1928	6	5.90	6.70	5.10	0.33	0.36	0.30
		1929	12	7.00	7.50	6.80	0.27	0.32	0.24
	Santa Clara County.....	1925	8	6.71	7.85	6.03	0.49	0.49	0.33
		1927	6	6.20	8.00	4.50	0.36	0.50	0.28
		1928	29	6.86	8.50	5.10	0.34	0.44	0.24
		1929	15	6.82	7.10	6.30	0.31	0.35	0.26
	Hollister.....	1925	4	6.21	6.75	5.68	0.43	0.52	0.35
		1926	4	6.97	7.20	6.70	0.31	0.35	0.27
	Salinas.....	1927	15	6.34	7.00	5.30	0.39	0.50	0.33
		1928	8	6.26	7.70	5.20	0.27	0.36	0.24
		1929	20	7.02	7.70	6.50	0.34	0.37	0.27
	Riverside.....	1925	6	5.02	5.41	4.56	0.31	0.38	0.26
		1927	7	5.23	5.60	4.00	0.29	0.40	0.21
		1928	3	5.20	5.60	5.20	0.38	0.51	0.28
		1929	11	5.97	6.40	5.60	0.26	0.33	0.22
Stone.....	Alameda County.....	1925	4	8.66	9.55	7.91	0.72	0.81	0.63
	San Fernando Valley.....	1925	4	6.20	6.54	6.06	0.42	0.59	0.39
	Davis.....	1925	1	6.10	.....	.....	0.54	.....	.....
Norton.....	Santa Clara County	1927	1	7.60	.....	.....	0.60	.....	.....
	San Mateo County	1925	1	6.30	.....	.....	0.47	.....	.....
Norton Selection	Riverside.....	1925	4	4.89	4.99	4.80	0.42	0.49	0.35
		1927	4	4.97	5.60	4.20	0.36	0.40	0.27
Norton.....	Fullerton.....	1926	12	6.39	7.50	5.80	0.47	0.58	0.43
		1926	26	6.00	6.50	5.60	0.41	0.47	0.36
		1929	12	8.60	9.20	7.70	0.43	0.47	0.40
	San Fernando Valley.....	1926	17	6.20	6.80	5.40	0.43	0.49	0.39
		1927	23	6.00	6.70	5.00	0.45	0.60	0.36
		1928	8	6.63	7.00	5.90	0.40	0.45	0.33
		1929	15	7.30	8.50	6.50	0.47	0.58	0.38
	El Monte.....	1925	4	6.16	6.27	6.06	0.41	0.42	0.39
		1926	11	6.16	6.50	5.70	0.45	0.48	0.43
		1927	28	5.87	6.00	5.90	0.45	0.46	0.44
		1928	12	6.25	6.80	5.70	0.45	0.52	0.38

In table 2 the data have been arranged according to variety as well as locality in order that comparison of different localities may be made upon a single variety. The northern California samples are presented first in each series.

Four fairly distinct kinds of climate are represented; first, the cool, foggy climate of the San Francisco Bay region and Salinas Valley; second, the moderately warm climate of the Santa Clara Valley where

TABLE 3
DATA OF 1925 SEASON ARRANGED TO SHOW EFFECT OF CLIMATE ON
TOTAL SOLIDS AND TOTAL ACID

Variety	Locality	Summer climate	Total solids, per cent			Total acid, grams per 100 cc		
			Average	Maximum	Minimum	Average	Maximum	Minimum
San Jose Canner.....	Alameda County.....	Cool, foggy....	7.02	7.89	5.86	0.48	0.77	0.29
	Santa Clara County..	Warm.....	6.71	7.85	6.03	0.49	0.49	0.33
	Sacramento.....	Warm.....	4.99	5.75	4.65	0.33	0.41	0.27
	Riverside.....	Hot, arid.....	5.02	5.41	4.56	0.31	0.38	0.26
Stone.....	Alameda	Cool, foggy....	8.66	9.55	7.91	0.72	0.81	0.63
	San Fernando Valley	Warm	6.20	6.54	6.06	0.42	0.59	0.39
	Davis*.....	Warm.....	6.10	.....	.....	0.54	.....	.....
Norton.....	San Mateo County*..	Warm	6.30	.....	.....	0.47	.....	.....
	El Monte.....	Warm.....	6.16	6.27	6.06	0.41	0.42	0.39
	Riverside	Hot, arid.....	4.89	4.99	4.80	0.42	0.49	0.35

* One sample only.

early morning high fogs are frequent during the summer; third, the moderately hot summer climate of the Sacramento and San Fernando Valleys; and fourth, the hot, arid summer climate of Riverside.

The tomatoes grown in the cool, foggy climate of the San Francisco Bay district were considerably higher in total solids than those of the same variety grown in warmer localities, and in general, the higher the average summer temperature, the lower was the total-solids content. Total acid did not follow a similar trend (table 4). Unfortunately for comparative purposes, different varieties are grown commercially in southern California than in northern California. The San Jose Canner and its derivatives predominate in the north, while the Norton, Globe, and Stone predominate in the south. The Canner varieties cannot be grown successfully in southern California because of their susceptibility to certain diseases prevalent in that region.

In order to demonstrate more clearly the effect of climate on total solids and total-acid content, some of the data of table 2 have been rearranged in table 3.

The San Jose Canner had 7.02 per cent total solids in Alameda County, only 4.99 per cent at Sacramento, and 5.02 per cent at Riverside. In other words, in the cool climate of the San Francisco Bay district this variety developed nearly one-third greater total-solids content than in the relatively hot climates of the Sacramento Valley and Riverside. The acidity of the tomatoes from Alameda County was much higher than that of tomatoes from Sacramento and Riverside counties.

TABLE 4

AVERAGES OF TOTAL SOLIDS AND TOTAL ACID OF ALL SAMPLES FROM
NORTHERN CALIFORNIA AND SOUTHERN CALIFORNIA
FOR 1925, 1926, 1927, 1928, AND 1929

Year	Average total solids, per cent		Average total acid, grams per 100 cc	
	Northern California	Southern California	Northern California	Southern California
1925	6.57	5.79	0.48	0.40
1926	6.01	6.16	0.29	0.44
1927	6.53	5.86	0.41	0.42
1928	6.47	6.40	0.30	0.41
1929	7.27	6.82	0.31	0.39
Average	6.53	6.08	0.37	0.43

The effect of climate on the Stone and Norton varieties was similar to that on the San Jose Canner. Compare data in table 3.

Kassab (1931) determined the total-solids content of tomatoes from several localities. The Santa Clara variety at Hayward had 9.00 per cent total solids; at Davis, 6.55 per cent; at Salinas, 6.92 per cent; and at Centerville, 9.80 per cent. The cool San Francisco Bay district climate favored development of high total-solids content in this variety also.

In table 4 the average total solids and total acid of all samples from northern California and from southern California are given for each of the years 1925, 1926, 1927, 1928, and 1929.

The averages for the five years for the two regions were obtained by taking the average of 277 samples from northern California and 236 from southern California. Most of the northern California samples were obtained in Alameda and Santa Clara counties, while most of the southern California samples came from the lower San Fernando Valley, El Monte, Fullerton, Buena Park, and Arlington.

Most of the northern California samples were of the San Jose Canner variety and its derivatives; most of those from southern California were of the Norton and Stone varieties. As will be shown later, these latter two varieties are usually much higher in total solids and total acid than the San Jose Canner variety when all are grown in the same locality. If this fact is taken into account, the advantage of the northern California tomatoes in total-solids content would be considerably greater than indicated in the table.

It would be of interest to compare the composition of tomatoes grown in California with those grown in eastern states; however, very little published data could be found on eastern varieties that are also grown

TABLE 5
TOTAL-SOLIDS CONTENT OF THE STONE AND MARGLOBE VARIETIES
GROWN IN MARYLAND AND IN CALIFORNIA

Sample No.	Stone, total solids, per cent		Marglobe, total solids, per cent	
	Maryland*	California	Maryland*	California
1	7.22	8.29	6.00	6.14
2	6.96	9.55	5.40	6.51
3	5.86	7.91	5.51	7.00
4	5.72	6.08	5.56	7.12
5	5.20	6.35	†	7.20
Average	6.19	7.64	5.62	6.89

* Data for Maryland samples from Appleman and Conrad (1927).

† Analysis not reported.

in California. Appleman and Conrad (1927) have published some data on total-solids content of the Stone and Marglobe grown in Maryland. We have also analyzed these varieties grown under California conditions. Comparative data are given in table 5.

The first 3 of the California samples of the Stone variety given in table 5 were grown at Centerville and the 2 remaining samples at Van Nuys in southern California. The samples of California-grown Marglobe tomatoes came from Van Nuys, Salinas, and Davis.

Bigelow and Fitzgerald (1915) published a number of analyses of pulps of tomatoes grown in eastern states, but did not give variety or locality where grown.

Their average values were: total solids, 4.37 per cent, total acid as citric, 0.31 per cent, and total sugar as invert, 2.19 per cent.

While it would not be justifiable to draw definite conclusions, because of the small number of samples of eastern-grown tomatoes, nevertheless, it would appear that California-grown tomatoes are somewhat higher

than the eastern ones in total solids. There appears to be little difference in total acid.

Effect of Locality on the Composition of Tomatoes from a Single Parent.—Analyses reported in table 10 show that there is considerable variation in composition of tomatoes from different plants grown from seed produced by a single parent. In order to eliminate this variable as far as possible, cuttings from a single plant of a Canner selection were grown at Davis by O. H. Pearson, of the Division of Truck Crops.

TABLE 6
EFFECT OF LOCALITY ON COMPOSITION OF TOMATOES FROM PLANTS
FROM A SINGLE PARENT

Plant	Davis				Berkeley			
	Total solids, per cent	Total acid, grams per 100 cc	Reducing sugar, per cent	Protein, per cent	Total solids, per cent	Total acid, grams per 100 cc	Reducing sugar, per cent	Protein, per cent
First Planting								
1	6.6	0.42	2.70	.....	10.8	0.42	6.44	1.65
2	6.2	0.38	3.08	.....	8.1	0.26	5.20	1.26
3	6.2	0.31	3.10	.....	8.0	0.37	4.92	1.28
4	6.0	0.35	2.49	.....	8.2	0.31	4.92	1.45
Average	6.25	0.34	2.84	.....	8.8	0.32	5.37	1.41
Second Planting								
1	6.2	0.38	3.49	1.25	9.7	0.38	5.76	1.61
2	6.2	0.32	2.96	1.27	7.7	0.31	5.08	1.22
	5.8	0.31	2.87	1.43	8.3	0.37	4.23	1.46
4	5.8	0.37	2.62	1.22	8.4	0.42	4.97	1.39
Average	6.0	0.36	2.98	1.29	8.5	0.37	5.01	1.42
Average of Both Plantings								
Average	6.1	0.35	2.91	1.29	8.6	0.34	5.19	1.41

Plantings of the young plants were then made simultaneously on each of two dates at Davis and Berkeley. Samples of tomatoes of apparently equal maturity were taken at both localities and were carefully analyzed. The plants in both plots were vigorous and normal in appearance. There was no evidence of lack of water in either planting. The analyses are given in table 6.

The fruit grown at Berkeley contained 2.5 per cent more total solids, 2.28 per cent more reducing sugar, and 0.12 per cent more protein than the fruit grown at Davis. The total-acid content of the fruit from the two localities was about equal. These results confirm those obtained by analysis of commercially grown samples from the Sacramento Valley and the San Francisco Bay district which are reported in tables 2 and 3.

EFFECT OF TIME OF PICKING ON TOTAL SOLIDS AND TOTAL ACID

The tomato-picking season usually lasts from late August to mid or late November in California. It is of interest to know the trend of change in composition with advance of the season in different localities. It is not practicable to give all the data obtained in this phase of the investigation; however, typical data are given in table 7.

TABLE 7
EFFECT OF TIME OF PICKING ON TOTAL SOLIDS AND TOTAL ACID

Locality	Variety	Reference No.	Date of picking	Total solids, per cent	Total acid, grams per 100 cc
Centerville.....	San Jose Canner..	1	Sept. 8, 1925	6.75	0.47
		2	Oct. 3, 1925	7.22	0.42
		3	Nov. 11, 1925	7.80	0.46
		4	Nov. 25, 1925	6.00	0.53
	Stone.....	5	Sept. 8, 1925	8.29	0.63
		6	Oct. 3, 1925	9.55	0.72
		7	Nov. 11, 1925	8.90	0.73
		8	Nov. 25, 1925	7.91	0.81
	Diener.....	9	Sept. 8, 1925	6.59	0.47
		10	Oct. 3, 1925	8.26	0.53
		11	Nov. 11, 1925	6.31	0.44
		12	Nov. 25, 1925	6.21	0.48
Sacramento.....	San Jose Canner..	13	Sept. 21, 1927	6.30	0.26
		14	Oct. 4, 1927	7.60	0.33
		15	Nov. 3, 1927	5.60	0.28
Fullerton.....	Norton.....	16	Oct. 3, 1927	6.43	0.41
		17	Oct. 10, 1927	6.10	0.43
		18	Nov. 2, 1927	6.00	0.37
		19	Nov. 16, 1927	5.61	0.41
San Fernando.....	Norton.....	20	Sept. 4, 1928	5.90	0.33
		21	Oct. 2, 1928	7.00	0.42
		22	Nov. 8, 1928	6.40	0.36

On the average, it will be seen that tomatoes picked during October were higher in total solids than those picked during September and November. Many other analyses not presented in the table support this finding. In November the days have become shorter and cooler, and cloudy skies are more frequent. These less favorable conditions probably account for the observed decline in total solids toward the end of the season. Why the total solids should be lower in September than in October is not clear. However, there were several cases in which the

total-solids content was higher in September than in October. For example, during the 1927 season, Norton tomatoes at Burbank picked on September 7 contained 6.5 per cent total solids; on October 18, 6.2 per cent; and November 12, 5.1 per cent.

Kassab (1931) reports that Norton tomatoes grown at Milpitas contained, on September 7, 6.78 per cent total solids; on October 7, 5.58 per cent; and on November 7, 5.42 per cent total solids. Similar results were obtained with the Santa Clara, Alameda Trophy, and Marglobe varieties. Evidently local conditions and seasonal variations in some cases have a greater effect than date of picking on the total-solids content.

Total-acid content did not appear to follow any definite trend with date of picking.

Appleman and Conrad (1927), reporting on tomatoes grown in Maryland, give the following values for total-solids content of the Bonny Best variety at different dates: August 16, 7.04 per cent; August 24, 6.75 per cent; September 7, 4.93 per cent; and September 14, 4.87 per cent. Similar values were obtained with the Greater Baltimore, Stone, and Marglobe.

Tomatoes picked in Maryland in August were higher in total solids than those picked in September. The season is shorter and the weather conditions are totally different from those in California; nevertheless, as is the case in California, early and midseason samples were higher in total solids than samples taken toward the end of the season.

ANNUAL VARIATION IN TOTAL SOLIDS AND TOTAL ACID

In table 2 are given the averages of total solids and total-acid content of tomatoes from several localities for three to five years. The average total-solids content of the samples from Sacramento for 1925, 1926, 1927, 1928, and 1929 were 4.99, 5.85, 6.50, 5.90, and 7.00 per cent respectively; and the total-acid values were 0.33, 0.31, 0.29, 0.33, and 0.27 grams per 100 cc. The greatest difference in average total solids was that between the 1925 and 1929 samples, a difference of 2.01 per cent. Samples from Alameda County for 1925, 1927, 1928, and 1929 contained 7.02, 6.61, 7.73, and 7.67 per cent average total solids, the greatest difference being between the 1927 and 1928 samples, which was 1.12 per cent. With the exception of the 1929 season, the samples of the Canner variety from Riverside showed relatively little variation in average total solids from year to year. The values for 1925, 1927, 1928,

and 1929 were 5.02, 5.23, 5.20, and 5.97 per cent. The total-acid values were 0.31, 0.29, 0.38, and 0.26 grams per 100 cc.

Samples from the San Fernando Valley for 1926, 1927, 1928, and 1929 contained 6.20, 6.00, 6.63, and 7.30 per cent average total solids and 0.43, 0.45, 0.40, and 0.47 grams per 100 cc of total acid.

Grand averages of all varieties are grouped in table 4 for the years 1925, 1926, 1927, 1928, and 1929 according to the two geographical regions, northern California and southern California. For northern California the maximum difference in total solids was between 1926 and 1929, a difference of 1.26 per cent, and for southern California between 1925 and 1929, 1.03 per cent. Northern California samples showed a maximum difference in total acid between 1925 and 1926 of 0.19 gram per 100 cc and southern California between 1926 and 1929 showed a difference of 0.05 gram per 100 cc. These variations are less than between samples from a single locality, and as might be expected where large numbers of samples are considered, the variations from locality to locality tend to counterbalance each other. Nevertheless, there is considerable variation in average composition from year to year, the 1929 average being considerably above the averages of the other years.

EFFECT OF WATER SUPPLY ON TOTAL SOLIDS AND TOTAL ACID

It is common knowledge that tomatoes from well-irrigated plants are larger, of brighter color, and less sweet in taste than from plants that are suffering because of lack of water. In table 8 are given several analyses of tomatoes from normal, well-irrigated plants and from non-irrigated plants grown in the same field.

The irrigated plants were large and the leaves were of a healthy, dark-green color. The nonirrigated plants were stunted and the leaves were pale green in color. The tomatoes from the irrigated plants were

TABLE 8

EFFECT OF WATER SUPPLY ON TOTAL SOLIDS AND TOTAL ACID OF TOMATOES

Sample No.	Locality	Year	Variety	Total solids, per cent		Total acid, grams per 100 cc	
				Well-irrigated plants	Non-irrigated plants	Well-irrigated plants	Non-irrigated plants
1	Walnut Creek.....	1925	Alameda Trophy.....	6.72	8.30	0.55	0.58
2	Walnut Creek.....	1925	San Jose Canner.....	6.88	8.11	0.74	0.71
3	Centerville.....	1930	Stone.....	9.80	10.30	.....	.....
4	Centerville.....	1930	San Jose Canner.....	8.95	11.00	.....	.....

large in size, juicy, and deep red in color; those from the nonirrigated plants were small, rather mealy in texture and the color was rather pale.

It is readily seen that the nonirrigated tomatoes were considerably higher in total solids. However, since the fruit from the nonirrigated plants was very small, poor in color, and of poor flavor, its higher total-solids content is of little practical importance.

EFFECT OF VARIETY ON TOTAL SOLIDS AND TOTAL ACID

A number of distinct varieties of tomatoes are grown commercially in California and there are also a number of selections or strains within each of several varieties, particularly the Canner and Stone. Analyses of several distinct varieties have been assembled in table 9. The samples from a given locality were grown in the same or adjoining plots and under similar conditions. In table 10 are given data illustrating the effect of seed selection on total solids and acidity. Many analyses have been omitted, but those included in table 10 are typical.

TABLE 9
EFFECT OF VARIETY ON TOTAL SOLIDS AND TOTAL ACID

Locality	Date of picking	Variety	Total solids, per cent	Total acid, grams per 100 cc
San Carlos, San Mateo County.....	Sept. 6, 1925.....	San Jose Canner.....	5.54	0.41
		Alameda Trophy.....	5.08	0.33
		Norton.....	6.30	0.47
		Santa Clara Canner.....	7.55	0.35
		Principe Borghesi.....	5.89	0.36
Centerville.....	Oct. 3, 1925.....	San Jose Canner.....	7.22	0.42
		Stone.....	9.55	0.72
		Diener.....	8.26	0.53
Salinas.....	Oct. 21, 1927.....	San Jose Canner.....	5.30	0.33
		Smooth Trophy.....	6.00	0.36
		Bonny Best.....	6.30	0.42
		Earliana.....	5.00	0.38
Davis.....	Sept. 6, 1928.....	Earliana.....	6.90	0.37
		San Jose Canner (411-1)*.....	6.30	0.32
		Trophy (150-4-4)*.....	5.80	0.31
		Principe Borghesi.....	5.50	0.28
	Sept. 21, 1928.....	King Humbert.....	5.50	0.25
Salinas.....	Sept. 30, 1928.....	Stone.....	7.56	0.44
Long Beach.....	Oct. 5, 1926.....	Stone.....	8.70	0.49
				0.30
Riverside.....	Sept. 8, 1927.....	San Jose Canner 035*.....	5.60	
		Norton selection.....	5.60	0.38
Burbank.....	Sept. 15, 1926.....	Stone.....	6.80	0.43

* Selection No.

The Stone variety was often higher in total solids and acidity than the other varieties compared with it in table 9. Kassab (1931) reports 9.80 per cent total solids for the Stone and 8.95 per cent for the San Jose Canner varieties picked at Centerville in October, 1930. Appleman and Conrad (1927) found the total-solids content of the Stone in Maryland considerably higher than that of the Bonny Best, Greater Baltimore, and Marglobe. Contrary to common opinion, the two Italian varieties, Principe Borghesi and King Humbert, as shown in table 9, were not particularly high in total solids and were also relatively low in acidity.

Some of the selections of the late J. T. Rosa are of much higher total-solids content than the average San Jose Canner. Selections made by

TABLE 10
EFFECT OF SEED SELECTION ON TOTAL SOLIDS AND TOTAL ACID

Locality	Date of picking	Variety	Selection No.	Sample No.	Totalsolids, per cent	Total acid, grams per 100 cc
Salinas.....	Sept. 24, 1928...	San Jose Canner.....	T-4175	1	7.10	0.27
			T-4151	2	6.40	0.27
			EC 1	3	6.50	0.24
			EC 3	4	6.30	0.25
		Santa Clara Canner.....	413	5	5.60	0.24
			142	6	5.90	0.26
			481	7	7.10	0.29
			483	8	8.00	0.23
			484	9	6.90	0.27
			681	10	7.70	0.28
	Sept. 12, 1929...	Morse Canner..	133-5F	11	5.90	0.31
			133-6A	12	7.70	0.46
			133-6B	13	7.10	0.44
			133-6C	14	6.30	0.39
			133-6D	15	7.10	0.45
			133-5E	16	6.50	0.33
			133-5F	17	5.90	0.31
Davis.....	Sept. 21, 1928...	San Jose Canner.....	401-1	18	5.50	0.33
			411-1	19	4.60	0.27
			75	20	5.97	0.40
	Oct. 3, 1925.....	San Jose Canner.....	Early	21	8.11	0.71
			Late	22	6.88	0.74
			72-2-1-p	23	5.48	0.43
			78-1-3	24	5.39	0.33
	Nov. 4, 1925...	San Jose Canner.....	78-1-2	25	6.84	0.42
			78-1-1	26	6.47	0.40
			57-1-0	27	6.29	0.44
Riverside.....	Sept. 30, 1925...	San Jose Canner.....	25041	28	5.16	0.38
			25001	29	4.56	0.26
			25042	30	4.86	0.31
			25038	31	5.13	0.31
			25043	32	5.41	0.30

the Morse Seed Company, in some cases, also have resulted in a remarkable increase in total-solids content. The Early Canner is an outstanding example. Typical data are given in table 10 to illustrate the effect of seed selection.

Fortunately, it was possible to secure from the experimental plots of the Morse Seed Company at Salinas, tomatoes grown in 1930 from seed selected in previous years. Composite samples of fruit from several plants of each selection were used for analysis in order to reduce the effect of variations from plant to plant. Some of the data are given in table 11. Samples 1, 2, 3, and 4 are of a single line; similarly 5, 6, and 7; and 8 and 9.

TABLE 11

COMPARISON OF COMPOSITION OF TOMATOES GROWN IN 1930 FROM SELECTED SEED
(Morse Seed Company)

Sample No.	Variety	Selection No.	Plants grown from seed stored since year indicated below	Total solids, per cent	Total acid, grams per 100 cc	Reducing sugars, per cent
1	Santa Clara Canner. {	9659	1926	6.4	0.32	.....
2		9658	1927	6.5	0.33	.....
3		9652	1928	6.6	0.32	.....
4		9653	1928	6.9	0.33	.....
5	San Jose Canner..... {	.....	1927	5.3	0.33	.....
6		9641	1929	7.0	0.37	3.28
7		9642	1929	6.8	0.42	2.84
8	Canner..... {	9651	1919	6.5	0.32	3.70
9		9650	1924	7.7	0.33	4.22

Evidently it is possible by seed selection to increase the total-solids content of a variety at least 2 per cent, or practically one-third. Therefore it would appear desirable and profitable for canners to give more attention to this method of improving existing varieties for tomato-products manufacture. The data here given, however, are too meager to demonstrate to what extent observed variation is due to crossing, mutation, and heterogeneity.

Naturally, the effect of selection is apt to be mixed; some of the progeny may be superior, some equally good, and some inferior to the parent stock. This is shown in samples 1 to 4 in table 11. Lesley and Rosa (1926), by three years' inbreeding and selection of the Santa Clara Canner variety, isolated lines differing greatly in smoothness, size, color, and time of maturity. Some of these lines were constant after the second generation, while others were variable even after three generations.

Composition of the fruit is, of course, not the only criterion by which tomato seed must be selected for propagation of tomatoes for canning and tomato-products manufacture. Size of the fruit, its color, flavor, and texture are all very important. The vigor of the plant, its resistance to disease, the yield of fruit per acre, and the time of ripening must also be taken into account. Therefore, the task of improving tomato varieties by crossing and seed selection is a complicated one. The point we wish to make is, that while chemical composition of the fruit should not be unduly stressed, nevertheless, it should not be ignored in systematic attempts to improve existing varieties.

TOTAL SOLIDS AND TOTAL-ACID CONTENT OF TOMATOES FROM DIFFERENT PLANTS

Composite samples of the fruit from each of 10 plants of San Jose Canner selection 9641, grown in the same row in the Morse Seed Company's plot at Salinas, were analyzed with the results as given in table 12.

TABLE 12
VARIATIONS IN COMPOSITION OF FRUIT FROM
CONSECUTIVE VINES OF A SINGLE
SELECTION

Plant No.	Total solids, per cent
1.....	7.7
2.....	6.9
3.....	6.9
4.....	7.0
5.....	7.1
6.....	7.0
7.....	7.0
8.....	7.5
9.....	6.9
10.....	6.9
Average.....	7.09

With the exception of fruit from plants Nos. 1 and 8, the various samples agree well in total-solids content. However, the fact that 2 plants out of 10 exhibited rather large deviation from the average shows the necessity of using composite samples from several plants if the representative composition of a given variety or selection is to be found. See also data in table 6.

TOTAL SOLIDS OF FRUIT FROM VARIOUS LOCATIONS ON THE PLANT

Samples of fruit of apparently equal ripeness were selected from the north, south, east, and west quarters and from the top center of each plant of three selections in the experimental plot of the Morse Seed Company at Salinas. The specimens from each location were combined and the resulting composite samples were analyzed. The data are given in table 13.

TABLE 13

TOTAL SOLIDS OF FRUITS FROM VARIOUS LOCATIONS ON THE SAME PLANT

Location	Total solids content in per cent		
	San Jose Canner, Selection No. 9642	Early Santa Clara Canner, Selection No. 9644	Santa Clara Canner, Selection No. 9647
North.....	6.4	6.2	6.0
West.....	6.8	6.6	6.0
South.....	6.8	6.9	6.0
East.....	6.3	6.5	5.9
Top center.....	6.3	6.3	6.2

It would appear that fruits from the west and south quarters of the plant are somewhat higher in total-solids content. The total acid of the samples from San Jose Canner 9642 were north, 0.43 grams per 100 cc; west, 0.44; south, 0.48; east, 0.40; and top center, 0.40.

Fruits from the top center of the plant were not remarkably high in total solids, although since they receive more sunlight than fruit on other portions of the plant they might be expected to be richer in total solids.

TOTAL-SOLIDS CONTENT OF DIFFERENT PORTIONS OF THE FRUIT

The cores, the locules (the jelly-like material around the seeds), and the interlocular walls and outer walls of individual fruits were segregated and composite samples of several fruits were used for analysis. Some of the data are given in table 14.

The average composition of the various portions and of the whole fruit of all the samples analyzed in this particular study are given in table 15.

TABLE 14
COMPOSITION OF DIFFERENT PORTIONS OF THE TOMATO FRUIT

Variety	Selection No.	Total solids, per cent			Total acid, per cent			Reducing sugars, per cent		
		Core	Locule	Walls	Core	Locule	Walls	Core	Locule	Walls
Canner.....	198-1-3	6.2	5.8	5.8	0.37	0.45	0.35	2.94	2.52	2.79
	198-1-4	6.0	6.0	5.8	0.37	0.54	0.33	2.66	2.07	2.53
	198-1-5	6.3	6.0	6.0	0.31	0.38	0.27	3.36	2.86	2.84
	198-2-2	5.0	5.0	5.0	0.28	0.35	0.30	2.86	2.34	2.39
	198-2-4	5.2	5.0	5.0	0.35	0.45	0.30	2.61	2.13	2.38
	198-3-2	5.2	5.1	5.1	0.32	0.36	0.26	3.47	3.15	3.76
	198-1-1	7.1	6.6	6.6	0.40	0.61	0.40	2.90	2.69	2.32
	198-1-2	6.3	6.0	6.2	0.36	0.54	0.36	3.30	2.90	2.96
	198-2-1	6.2	5.9	6.2	0.31	0.41	0.31	3.18	2.72	3.04
	198-2-2	5.8	5.1	5.5	0.31	0.42	0.30	2.60	2.13	2.37
	198-2-4*	6.3	5.8	5.9	0.36	0.59	0.35	1.89	1.51	1.50
	198-1-1*	6.3	6.2	6.2	0.38	0.55	0.37	3.61	3.26	3.30
	198-1-2*	6.3	5.8	6.2	0.30	0.41	0.19	2.77	2.30	2.85
Santa Clara Canner.....		5.1	5.0	5.0	0.38	0.36	0.27	3.30	2.98	3.07

* Fruit from second picking.

TABLE 15
AVERAGE COMPOSITION OF THE DIFFERENT PORTIONS AND OF THE WHOLE FRUIT

Portion	Total solids, per cent	Total acid, grams per 100 cc	Reducing sugars, per cent	Protein,* per cent	Acid hydrolyzable,* per cent
Cores.....	6.00	0.32	3.17	1.29	0.258
Locules.....	5.80	0.46	2.54	1.20	0.055
Walls.....	5.83	0.32	2.73	1.31	0.292
Whole fruit.....	5.90	0.37	2.87	1.30	0.255

* Protein and acid-hydrolyzable material were not determined on all samples and hence are not presented in table 14.

It is apparent that the core is relatively high in total solids, reducing sugar, protein, and acid-hydrolyzable material. The locular material (the jelly-like substance in the seed cavities) is higher in total acid but lower in total solids, reducing sugar, protein, and acid-hydrolyzable material than the core and the walls.

PROTEIN CONTENT OF TOMATOES

The protein content of 110 samples about equally distributed between the 1927, 1928, and 1931 seasons was determined. Typical average results and averages for each season together with the grand average of all samples are given in table 16.

Considerable variation in protein content was found in samples of the same variety from a single location, in samples from different locali-

TABLE 16
PROTEIN CONTENT OF CALIFORNIA TOMATOES

Variety	Locality	Year	Number of samples	Protein, per cent	Total solids, per cent	
Canner (198-1-1)*.....	Davis.....	1931	2	1.25	6.2	
Canner (198-1-2)*.....			2	1.27	6.2	
Canner (198-1-4)*.....			2	1.22	5.8	
Canner (198-1-3)*.....			2	1.32	6.2	
Canner (198-2-4)*.....			2	1.34	5.0	
	Berkeley.....		8	1.41	8.8	
	Davis.....		2	1.29	6.1	
Canner.....	Salinas.....	1928	2	0.81	7.5	
	San Jose.....		2	1.31	7.1	
			2	0.90	7.1	
Santa Clara Canner.....	Salinas.....	1927	2	0.67	5.5	
			2	0.84	6.2	
			2	0.77	6.2	
		1928	2	0.63	7.7	
			1	0.74	7.0	
Trophy.....	Hayward.....		2	1.09	6.8	
Norton.....	San Fernando.....	1928	2	0.85	6.0	
	El Monte.....		2	1.09	6.3	
			2	0.83	6.8	
			2	0.82	6.9	
	Van Nuys.....	1927	3	1.04	5.8	
2			1.08	6.4		
2			0.77	5.2		
2			0.75	5.2		
2			0.85	6.1		
Fullerton.....	1928	3	0.82	6.0		
		2	1.00	6.8		
		2	0.85	5.6		
		Miscellaneous.....	1928	46	0.92	6.4
			1927	21	0.83	5.8
1928	69		0.89	6.6		
Canner.....	Averages.....	1931	20	1.34	5.8	
		1927	110	0.97	6.2	
		1928				
		1931				

*Selection No.

ties, and in samples of different seasons. In general, high total-solids content was accompanied by high protein, although there was no close, direct relation. The lowest observed protein concentration was 0.55 per cent accompanied by 5.2 per cent total solids; the sample was of a seed selection of the Santa Clara Canner (included in averaged data in table 16) grown at Salinas in 1928. The highest protein content was

that of a sample of Canner selection (table 6) grown in Berkeley in 1931. It contained 1.65 per cent protein and 10.8 per cent total solids. The grand average of 110 samples was 0.97 per cent protein and 6.2 per cent total solids. The 1931 samples were considerably higher in protein content than the 1927 and 1928 samples; possibly the drier season of 1931 was in part responsible for this difference.

Sherman (1915) gives the average protein content of 19 samples of tomatoes as 1.20 per cent and total solids as 6.0 per cent.

Chatfield and Adams (1931) report the average protein content of 34 samples as 1.0 per cent; maximum 1.8 per cent and minimum 0.7 per cent. The average total-solids content was 5.9 per cent. Neither Sherman nor Chatfield and Adams state the source of their samples.

It would appear that tomatoes possess, on the average, about 1.00 per cent to 1.10 per cent of protein.

From table 15 it may be seen that the cores and walls of the tomato are slightly higher in protein than the locules.

SUCROSE, REDUCING SUGARS, AND DEXTROSE-LEVULOSE RATIO

As shown in table 1, most of the sugar in tomatoes is present in the form of reducing sugar; there is very little, usually less than 0.1 per cent, of sucrose.

During the 1926 season 16 samples were analyzed for reducing sugars; during 1928, 70 samples; during 1929, 93 samples; and during 1931, 33 samples. Typical data are given in table 17.

In general, high total solids are accompanied by a high reducing-sugar content. The nonsugar-solids content was not a constant, but like the sugar tended to vary with the total solids. On the average, nonsugars by difference were about equal to the sugars, if slightly less than 0.1 per cent is allowed for sucrose. However, in individual samples the ratio varied considerably. The Norton did not differ materially from the San Jose Canner in reducing-sugar content. Tomatoes grown in Berkeley showed a considerably higher content of reducing sugars than of nonsugars; in those grown at Davis from the same parent as at Berkeley, the nonsugar solids exceeded the sugars. This finding would indicate that locality affects the sugar to nonsugars ratio materially.

By inversion of a sample in 1931 with invertase there was found an average of 0.027 per cent sucrose and by inversion with HCl a like amount in triplicate analyses. Rosa (1925, 1926) reported 0.03 to 0.04 per cent sucrose in Stone and Globe tomatoes grown at Davis. Benoy

TABLE 17
REDUCING-SUGARS CONTENT OF TOMATOES, ON A WET BASIS

Variety	Locality	Year	Sample No.	Total solids, per cent	Reducing sugars, per cent	Nonsugar solids by difference, per cent
San Jose Canner	Sacramento.....	1926	1	6.5	4.42	2.08
			2	6.3	3.46	2.84
	San Jose.....	1929	3	7.1	3.88	3.22
			4	6.9	3.50	3.40
			5	6.5	3.54	2.96
	Centerville.....		6	8.1	3.90	4.20
			7	8.8	4.16	4.64
			8	7.6	4.00	3.60
			9	8.1	4.10	4.00
	Sacramento.....	1929	10	6.9	3.30	3.60
			11	6.8	3.36	3.44
	Hayward.....		12	7.0	3.03	3.97
			13	8.0	4.05	3.95
	Riverside.....		14	8.5	4.57	3.93
			15	5.9	2.74	3.16
			16	5.6	2.55	3.05
Canner (198-6-3)*.....	Davis.....	1931	17 to 33	5.90	2.87	3.03
			34	6.25	2.84	3.41
	Berkeley.....		35	6.00	2.98	3.02
			36	8.80	5.37	3.43
			37	8.50	5.01	3.49
Burbank.....	1926	38	6.80	3.30	3.50	
	1929	39	6.50	3.12	3.38	
Norton.....	Fullerton.....	1929	40	7.00	3.33	3.67
			41	6.40	3.20	3.20
			42	7.70	2.96	4.74
	Van Nuys.....	1926	43	8.50	3.60	4.90
			44	7.10	3.56	3.54
			45	6.40	3.38	3.02
			46	6.40	3.29	3.11
			47	6.40	3.34	3.06
	Averages	1926		6.80	3.46	3.34
		1928		6.45	3.45	3.00
1929			7.27	3.29	3.98	
1931			6.60	3.46	3.14	
1926						
1928			6.86	3.38	3.48	

* Selection No.

and Webster (1930) were unable to find any sucrose in the samples analyzed by them.

It is evident that the sucrose content of tomatoes is at most very low, probably less than 0.05 per cent in most cases.

The dextrose-levulose ratio was determined on typical samples from the San Francisco Bay district and from southern California. Total

TABLE 18

DEXTROSE-LEVULOSE CONTENT OF CALIFORNIA TOMATOES, 1932 SEASON

Sample No.	Dextrose, per cent	Levulose, per cent	Total reducing sugars, per cent	Ratio of dextrose to levulose
Southern California samples				
1.....	2.06	1.85	3.91	1.11
2.....	2.06	1.71	3.77	1.20
3.....	1.93	1.73	3.68	1.11
4.....	2.11	1.68	3.79	1.25
5.....	2.04	1.81	3.85	1.13
6.....	2.15	1.84	3.99	1.17
7.....	2.06	1.92	3.98	1.07
8.....	1.99	1.91	3.90	1.04
9.....	1.98	1.92	3.90	1.03
10.....	2.09	1.97	4.06	1.06
11.....	1.89	1.59	3.48	1.19
Average.....	2.03	1.80	3.84	1.17
Northern California samples				
12.....	2.50	2.04	4.54	1.22
13.....	2.37	1.97	4.34	1.20
14.....	2.35	1.81	4.16	1.30
15.....	2.24	1.73	3.97	1.29
16.....	2.39	1.96	4.35	1.22
17.....	2.12	1.78	3.90	1.19
Average.....	2.33	1.88	4.21	1.24

reducing sugar was determined by the Shaffer-Hartmann method (1921), and dextrose by the Lothrop and Holmes method (1931). The latter method consists of selective oxidation of the dextrose in alkaline iodine solution. The data are presented in table 18.

Apparently the dextrose content is definitely and consistently higher than the levulose content. The average ratio of dextrose to levulose for the 17 samples was 1.19. It is of interest that it was slightly lower for the southern California samples than for those from northern California. This may be due to effect of variety or climate.

STARCH CONTENT OF TOMATOES

Tomatoes contain very little to no starch. Consequently only brief study was made of this constituent. It was determined after inversion by diastase as previously described (page 8).

By diastasic inversion, an average of 0.045 per cent starch was found. This value is much less than that of the total acid-hydrolyzable material. This result compares favorably with those of Rosa (1925, 1926) who reported 0.044, 0.052, 0.034, 0.012, and 0.022 per cent starch in ripe tomatoes grown at Davis. These values are expressed upon the wet basis.

ACID-HYDROLYZABLE MATERIAL

Acid-hydrolyzable material was determined as previously described (page 8). Average results of analyses of different portions of the fruit are given in table 15. The acid-hydrolyzable content of the cores was 0.258 per cent; of the locules, 0.055 per cent; of the walls, 0.292 per cent; while that of the entire fruit was 0.255 per cent. It will be seen that the content of acid-hydrolyzable material is several times that of starch as determined by diastase inversion.

PECTIN AND PROTOPECTIN CONTENT OF TOMATOES

The pectin content of tomatoes, as affected by variety, ripeness, locality, and water supply was determined by the Wichmann (1922, 1923) method during the 1930 season by M. A. Kassab, a graduate student in the Fruit Products Laboratory of the University of California. In a few cases protopectin was also determined. In order to conform to the usual practice and to permit comparison of Kassab's results with those of Appleman and Conrad the data are presented on the *dry basis*, that is, pectin as percentage of total dry material present in the whole fruit. All other data in this publication are presented on the fresh, or *wet basis*. The whole fruit rather than merely the pulp was analyzed.

The data of Kassab show that the pectin content varies considerably with the variety, although in most of the samples analyzed the pectin varies more or less directly according to the total-solids content. It would appear also that the Santa Clara Canner is, on the average, richer in pectin than the other varieties examined.

TABLE 19
EFFECT OF RIPENESS ON PECTIN AND PROTOPECTIN CONTENT OF TOMATOES,
MILPITAS, 1930*

Variety	Stage of development	Approx. diameter, inches	Total solids, per cent of fresh fruit	Protopectin, per cent on dry basis	Pectin, per cent on dry basis
Early Canner.	Very green.....	1	10.60	2.32	0.87
		1½	10.22	2.25	0.87
		2	9.17	2.20	0.87
	Moderately green.....	2½	8.22	1.80	1.25
	Yellow green.....	3	7.50	1.25	2.28
Alameda Trophy	Full red.....	3	6.67	0.10	2.58
	Very green.....	1	11.10	2.27	0.77
		1	10.87	1.37	0.94
		2	9.45	1.30	0.98
	Yellow green.....	3	8.95	0.11	2.20
Santa Clara Canner.....	Full red.....	3	7.95	0.03	2.70
	Hard green.....	3	11.45	2.79	†
	Full red.....	3	9.00	trace	2.44
	Overripe.....	3	8.55	trace	1.57

* From analysis reports of M. A. Kassab, graduate student.

† Not determined.

Kassab found that as the total solids decreased towards the end of the season, the pectin decreased also. Appleman and Conrad (1927), reporting on tomatoes grown in Maryland, found relatively little change in pectin concentration in the Bonny Best between August 14 and September 14; corresponding total-solids determinations were not given. They found greater change in pectin than in pectin plus protopectin. Average pectin plus protopectin (total pectic constituents) concentrations, expressed on dry basis, of all varieties studied by them varied as follows:

August 16.....	2.35 per cent
August 24.....	2.85 per cent
August 30.....	3.18 per cent
September 7.....	3.79 per cent
September 14.....	3.79 per cent
September 21.....	4.00 per cent
Average	3.52 per cent

Kassab reported that tomatoes grown at Davis were lower in pectin as well as in total solids than those grown in the cool, foggy climate of Hayward and Centerville.

Lack of water, he found, caused an increase in pectin as well as in total solids of tomatoes grown near Centerville. Very green tomatoes contained more protopectin than pectin. As the fruit ripened the protopectin decreased and the pectin increased (see table 19). At full ma-

turity, the Wichmann (1922, 1923) method indicated that the protopectin had decreased to about 0.1 per cent. In passing, it may be noted that the total-solids content of partly grown, green tomatoes was higher than in the ripe fruit.

Appleman and Conrad (1927) also found a change of protopectin to pectin during ripening, although their data show less change than that found by Kassab.

The pectin constitutes only a relatively small portion of the total solids. The average total-solids content of the five varieties studied was 7.25 per cent of the fresh fruit and the pectin, 1.86 per cent on the dry basis. The fresh tomatoes would then contain only 0.13 per cent pectin.

Appleman and Conrad found a similar concentration of pectin; thus the average pectin content of the Bonny Best was 2.11 per cent on the dry basis and about 0.125 per cent on the wet basis.

“INSOLUBLE SOLIDS BY DIFFERENCE”

The proportion of suspended matter in tomato products affects their consistency and appearance. However, the content of suspended matter is affected materially by the thoroughness of the screening operation in pulping. Consequently, unless the history of given pulp samples is known, it is impossible to determine what proportion of any observed variation is due to manufacturing methods and what proportion is due to variety, weather conditions, date of picking, etc.

Solids content of the unfiltered pulps and of the clear filtrates of most of the 1925 samples were determined by drying in vacuo. Insoluble-solids content was determined by difference, that is, by subtracting the solids content of the filtrate from that of the unfiltered pulps. Insoluble-solids content so determined is not necessarily the true insoluble solids. The latter can only be determined by filtering or centrifuging off the insoluble solids, repeatedly washing with water to remove soluble matter, drying, and weighing the residue.

However, “insoluble solids by difference” is of some interest as an index of variation in composition of tomato pulps. The average insoluble solids by difference of 75 samples was 0.74 per cent and the average total solids was 6.50 per cent. The maximum insoluble-solids value was 1.11 per cent and the minimum 0.42 per cent. Only 10 samples out of 75 contained less than 0.60 per cent insoluble solids, while 23 samples were above 0.80 per cent. The remainder lay between 0.60 and 0.80 per cent. High total-solids content was usually accompanied by high insoluble solids.

Bigelow and Fitzgerald (1915) give a range of insoluble solids, in unconcentrated pulps determined directly, of 0.40 to 2.02 per cent; their average being 0.701 per cent.

pH VALUE OF JUICE OF TOMATOES

The hydrogen-ion concentrations, expressed as pH values, of 76 filtrates from pulp samples were determined during the 1925 season by a hydrogen electrode and potentiometer. The average pH value was 4.1. The maximum was 4.4 and the minimum was 3.8. Most of the samples ranged in pH from 4.0 to 4.2; 53 samples out of 75 lay within this range. High acidity (titratable) was usually accompanied by low pH and low acidity by high pH value.

SUMMARY

The average total solids and sugar of tomatoes of a given variety grown in the cool, foggy climate of the San Francisco Bay region were higher than those of the same varieties grown in the Sacramento Valley.

The average total-solids content of all samples from southern California for a five-year period was 0.55 per cent lower than that of the northern California samples. In general, the higher the summer temperature, the lower was the total-solids content.

From the data at hand, tomatoes grown in California appear to be higher in total solids than those grown in the eastern United States.

Tomatoes picked in November were considerably lower in total solids than those picked during October and September. In most seasons the tomatoes picked during October were somewhat higher in total solids than those picked in September.

Tomatoes from plants suffering from lack of water were higher in total solids than those from well-irrigated plants.

Of the important commercial varieties, the Stone was consistently highest in total solids and total acid. The Early Canner was also exceptionally high in total solids. Analyses of many samples of tomatoes grown from seed selections indicated a wide range of variation in total solids and total acid. Seed selection has been found an effective means of altering the composition of a given variety of tomato.

Tomatoes from adjacent plants and from different locations on a single plant were found to vary considerably in composition.

Analyses of the cores, locules, and walls showed the locular material to be higher in total acid and slightly lower in total solids, reducing sugars, and protein than the cores and walls. The cores were richest

in total solids and reducing sugars. The locular material was much lower than the walls and cores in acid-hydrolyzable material.

The average protein content of samples from three seasons' collections was 0.97 per cent.

Practically all of the sugars present in tomatoes were found to be reducing sugars. Sucrose concentration was found to be less than 0.05 per cent. Tomatoes do not contain a very active invertase.

The starch content of tomato pulp was found to be less than 0.05 per cent.

The pectin content of ripe tomatoes varied considerably with the variety, time of picking, ripeness of the fruit, and locality.

The insoluble solids by difference averaged 0.74 per cent, but ranged in irregular manner from 0.42 to 1.11 per cent.

The average pH value of the 1925 samples was 4.1; most of the pH values lay between 4.0 and 4.2.

The investigation definitely shows that tomatoes vary sufficiently in composition to warrant purchasing them on the basis of total-solids content when they are to be used in the manufacture of tomato products.

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